ON THE PREDICTION OF SEPARATION BUBBLES USING A MODIFIED CHEN-THYSON MODEL

by

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OUTLINE

BACKGROUND

ANALYSIS OF NACA 65–213 SEPARATION BUBBLE USING CEBECI'S VISCOUS–INVISCID INTERACTION METHOD

ANALYSIS OF NACA 0012 SEPARATION BUBBLE USING NAVIER–STOKES METHOD

COMPARISON WITH EXPERIMENT

SUMMARY

ANALYSIS

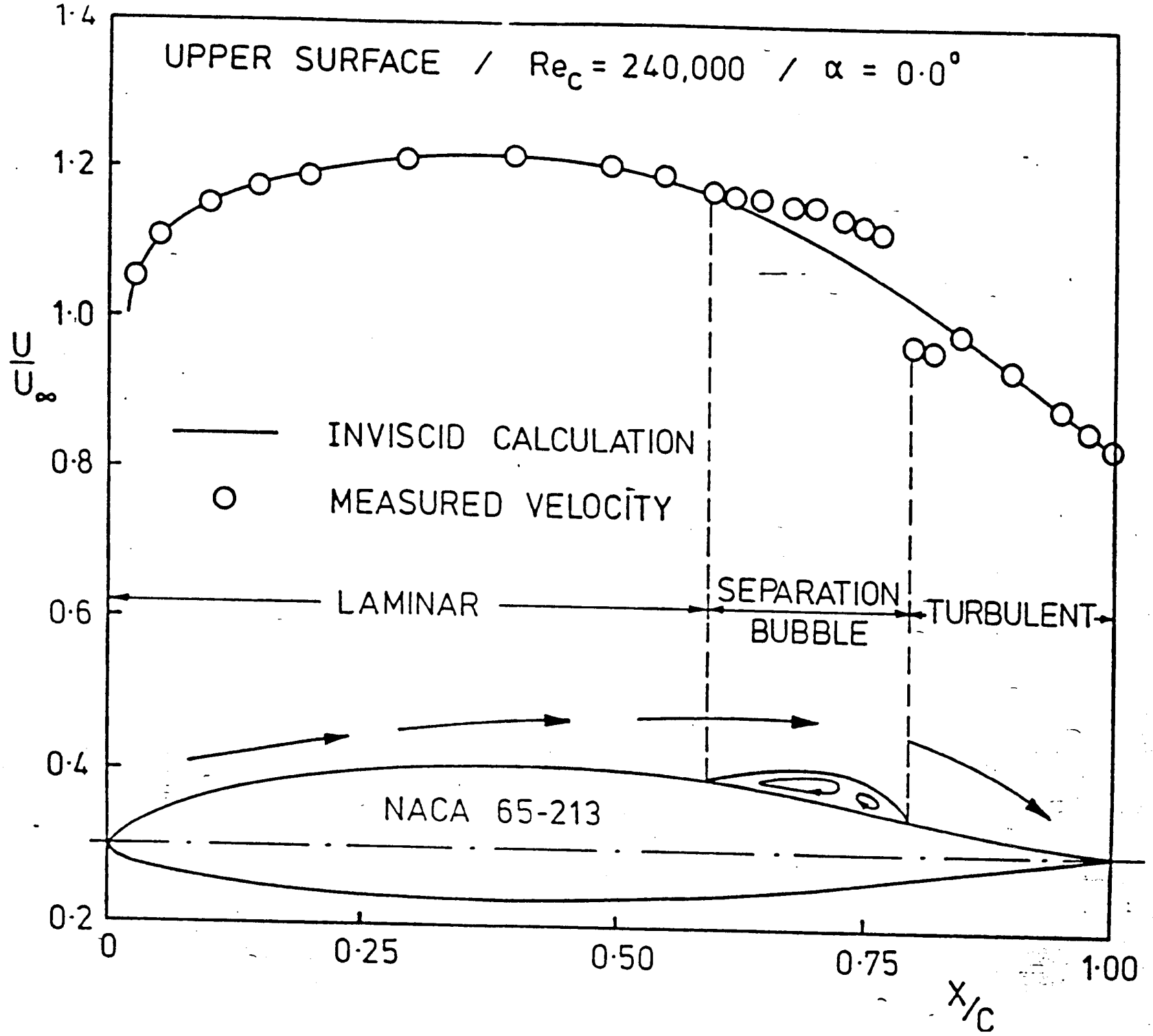
OF

NACA 65-213 AIRFOIL

USING

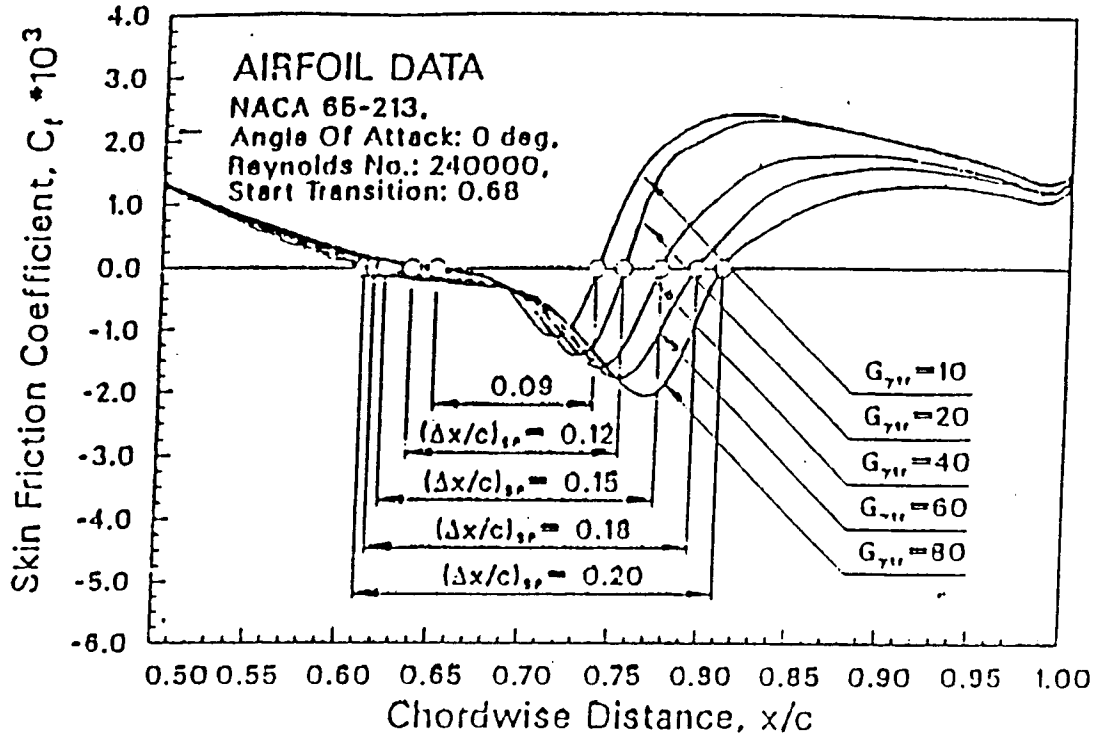
VISCOUS-INVISCID INTERACTION

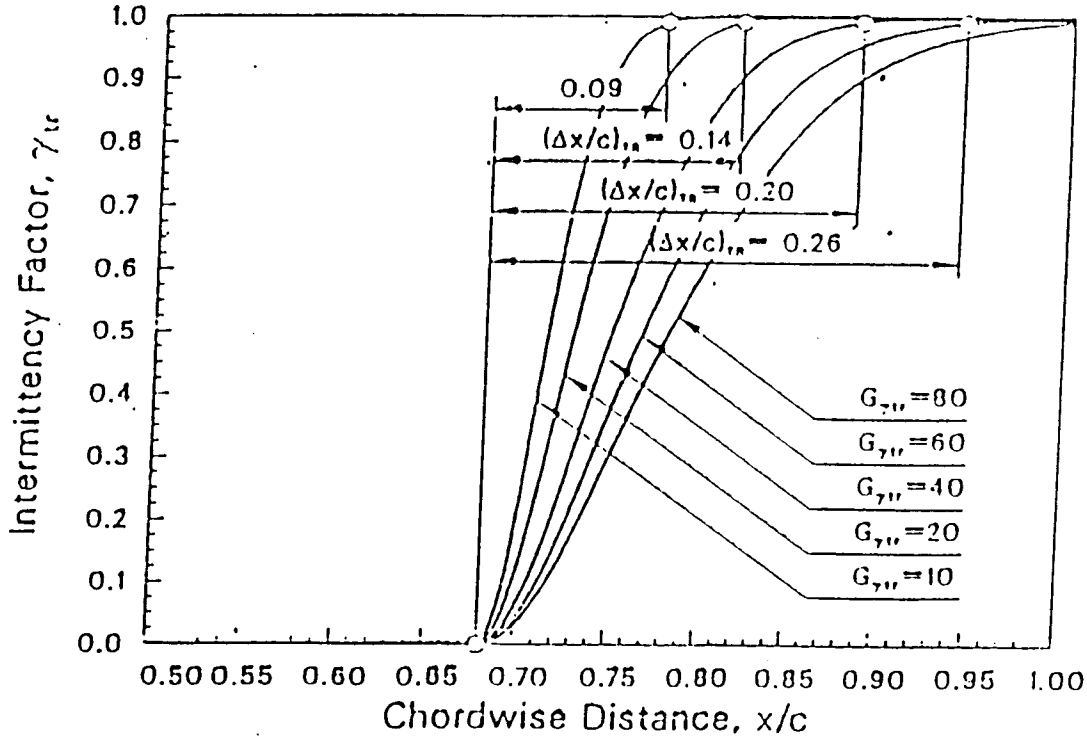
METHOD

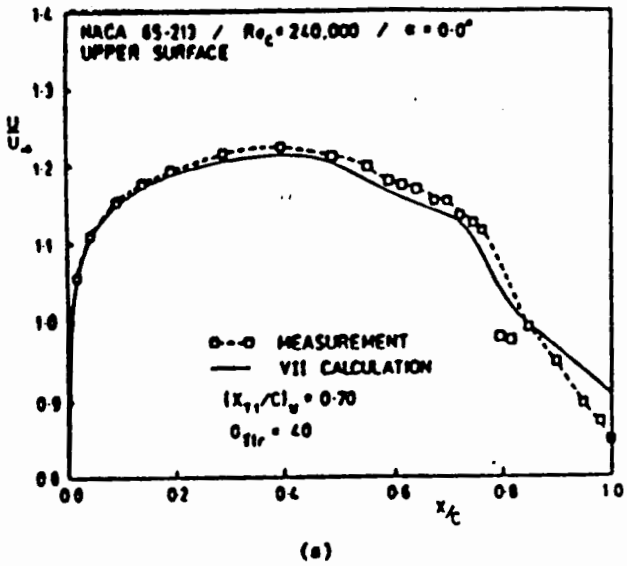

UPPER SURFACE / Re_c = 240,000 / α = 0·0°
1·4
1·2
1·0
0·8
0·6
0·4
0·2
U/U∞
INVISCID CALCULATION
MEASURED VELOCITY
LAMINAR
SEPARATION BUBBLE
TURBULENT
NACA 65-213
0
0·25
0·50
0·75
1·00
X/C

Chen and Thyson

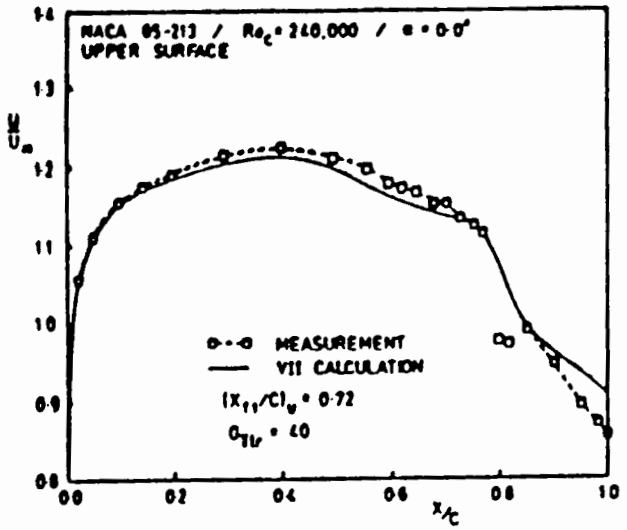
$$\gamma_{tr} = 1 - \exp\left[-\frac{u_e^3}{G_{\gamma_{tr}} v^2} R_{x_{tr}}^{-1.34} (x - x_{tr}) \int_{x_{tr}}^{x} \frac{d\xi}{u_e} \right]$$


AIRFOIL DATA
NACA 65-213,
Angle Of Attack: 0 deg,
Reynolds No.: 240000,
Start Transition: 0.68
Skin Friction Coefficient, $C_f * 10^3$
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
0.09
$(\Delta x/c)_{ss}$ = 0.12
$(\Delta x/c)_{ss}$ = 0.15
$(\Delta x/c)_{ss}$ = 0.18
$(\Delta x/c)_{ss}$ = 0.20
$G_{\gamma\prime\prime}$=10
$G_{\gamma\prime\prime}$=20
$G_{\gamma\prime\prime}$=40
$G_{\gamma\prime\prime}$=60
$G_{\gamma\prime\prime}$=80
0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
Chordwise Distance, x/c

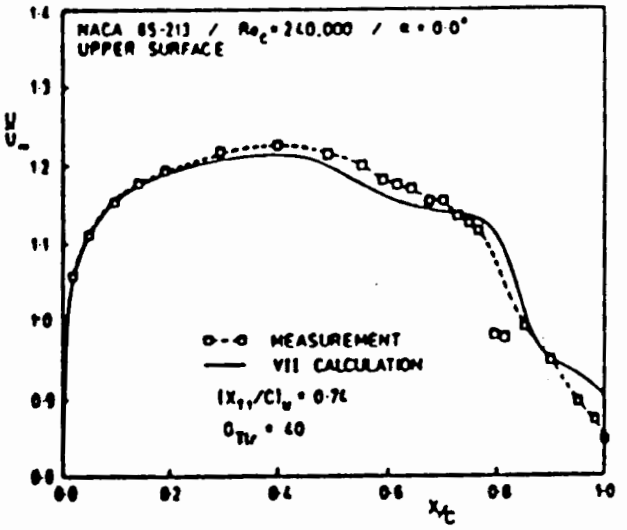

Intermittency Factor, γ_{tr}
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.09
$(\Delta x/c)_{tr}$ = 0.14
$(\Delta x/c)_{tr}$ = 0.20
$(\Delta x/c)_{tr}$ = 0.26
$G_{\gamma\prime\prime}$=80
$G_{\gamma\prime\prime}$=60
$G_{\gamma\prime\prime}$=40
$G_{\gamma\prime\prime}$=20
$G_{\gamma\prime\prime}$=10
0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
Chordwise Distance, x/c



(a)

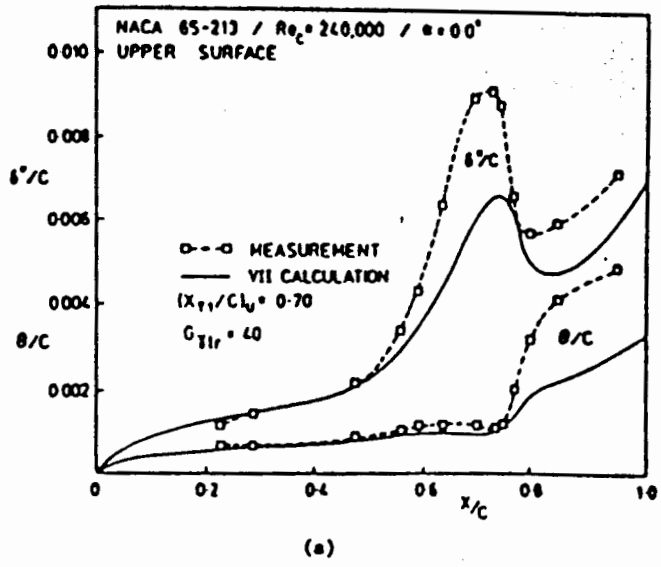


(b)

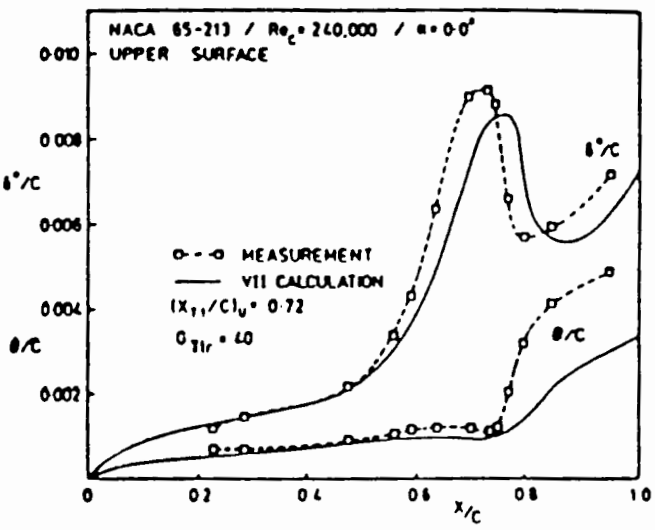


(c)

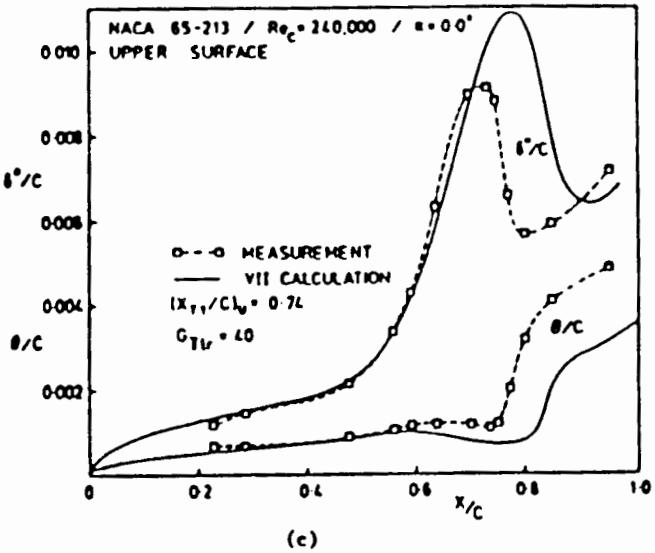
Calculated and measured inviscid surface velocity distributions: G_{ytr} fixed, varying $(x_{Tl}/c)_u$



(a)

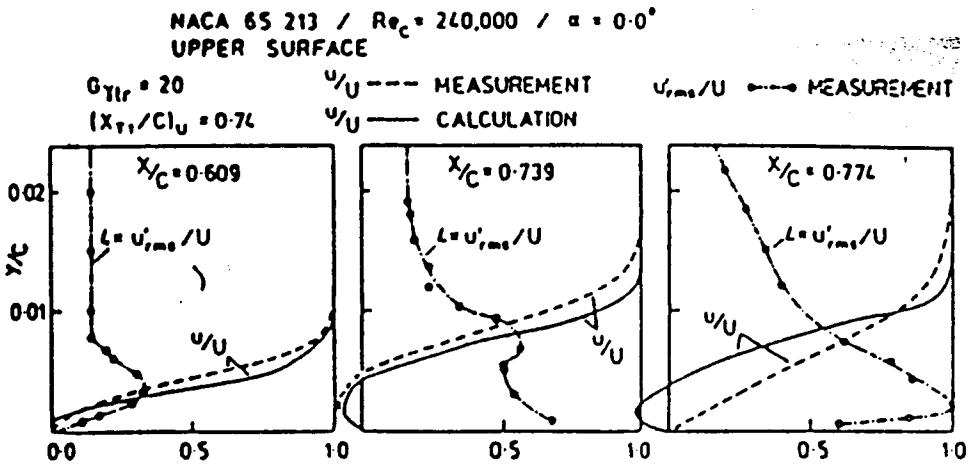


(b)

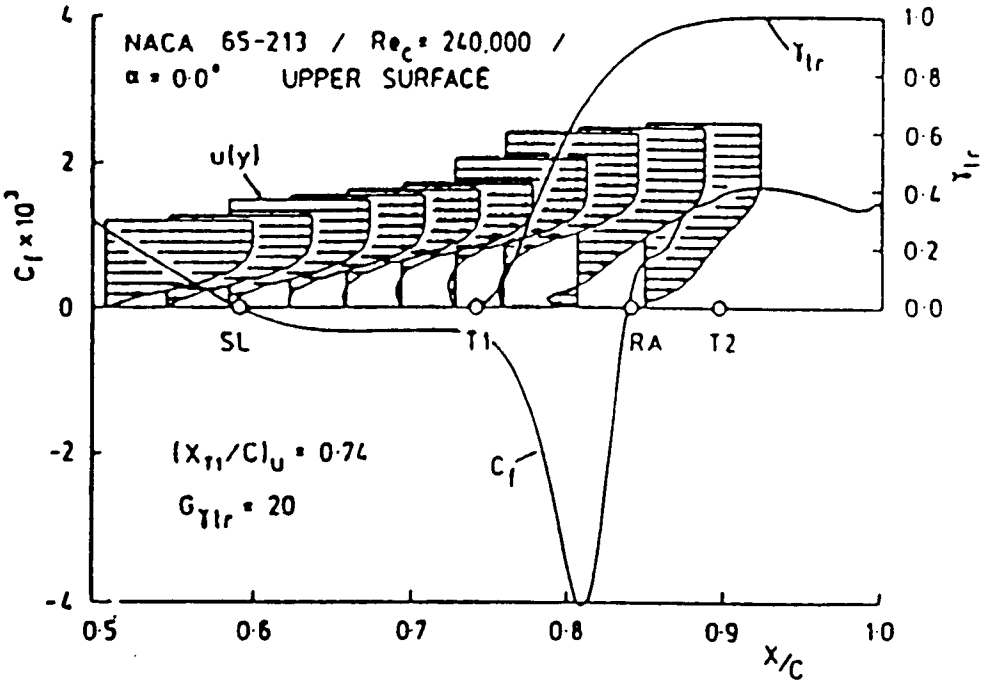


(c)

Calculated and measured displacement and momentum thicknesses of viscous layer: G_{ytr} fixed, varying $(x_{Tl}/c)_u$



Velocity and turbulence intensity profiles in separation bubble region



Typical computed separation bubble flow

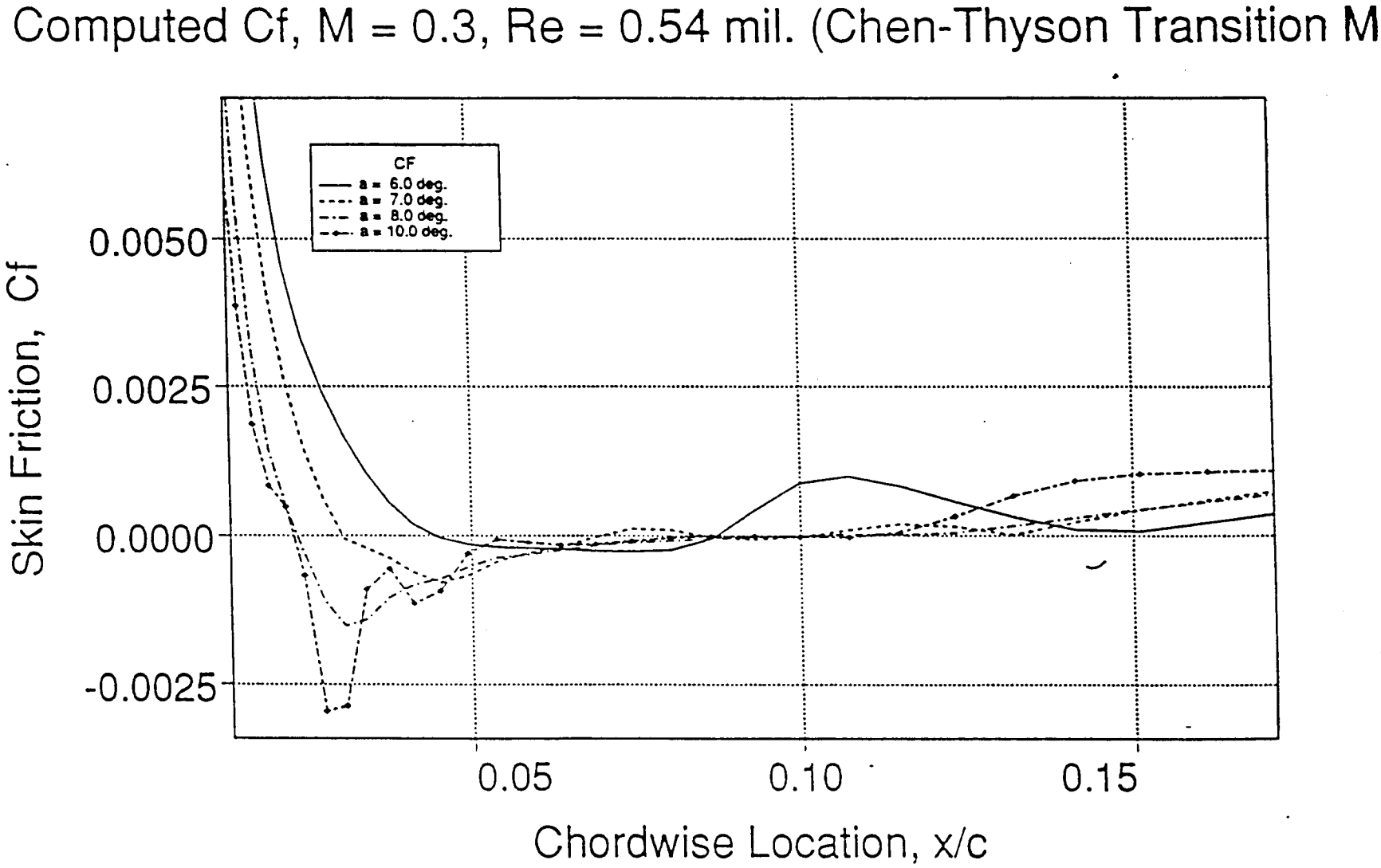
ANALYSIS

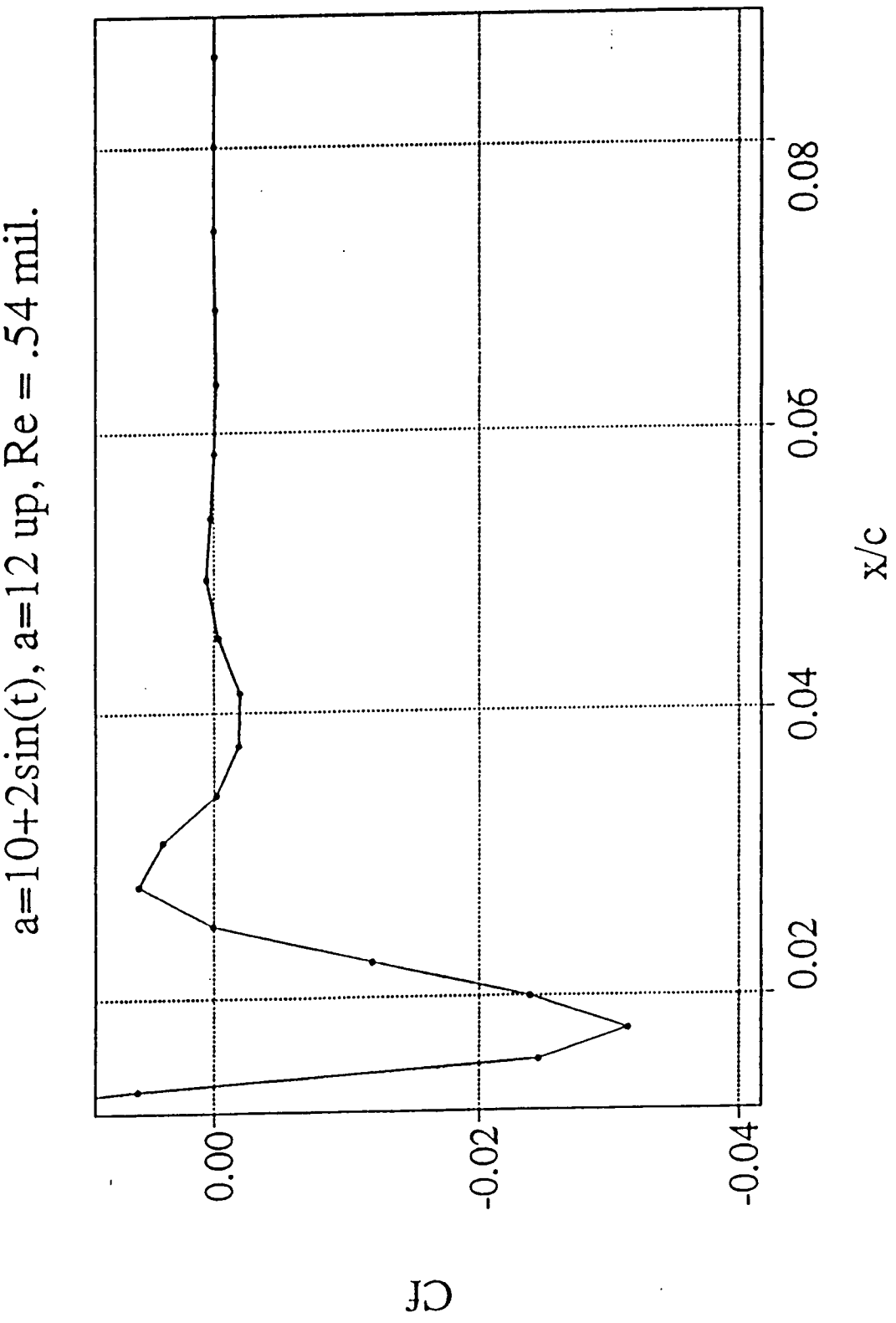
OF

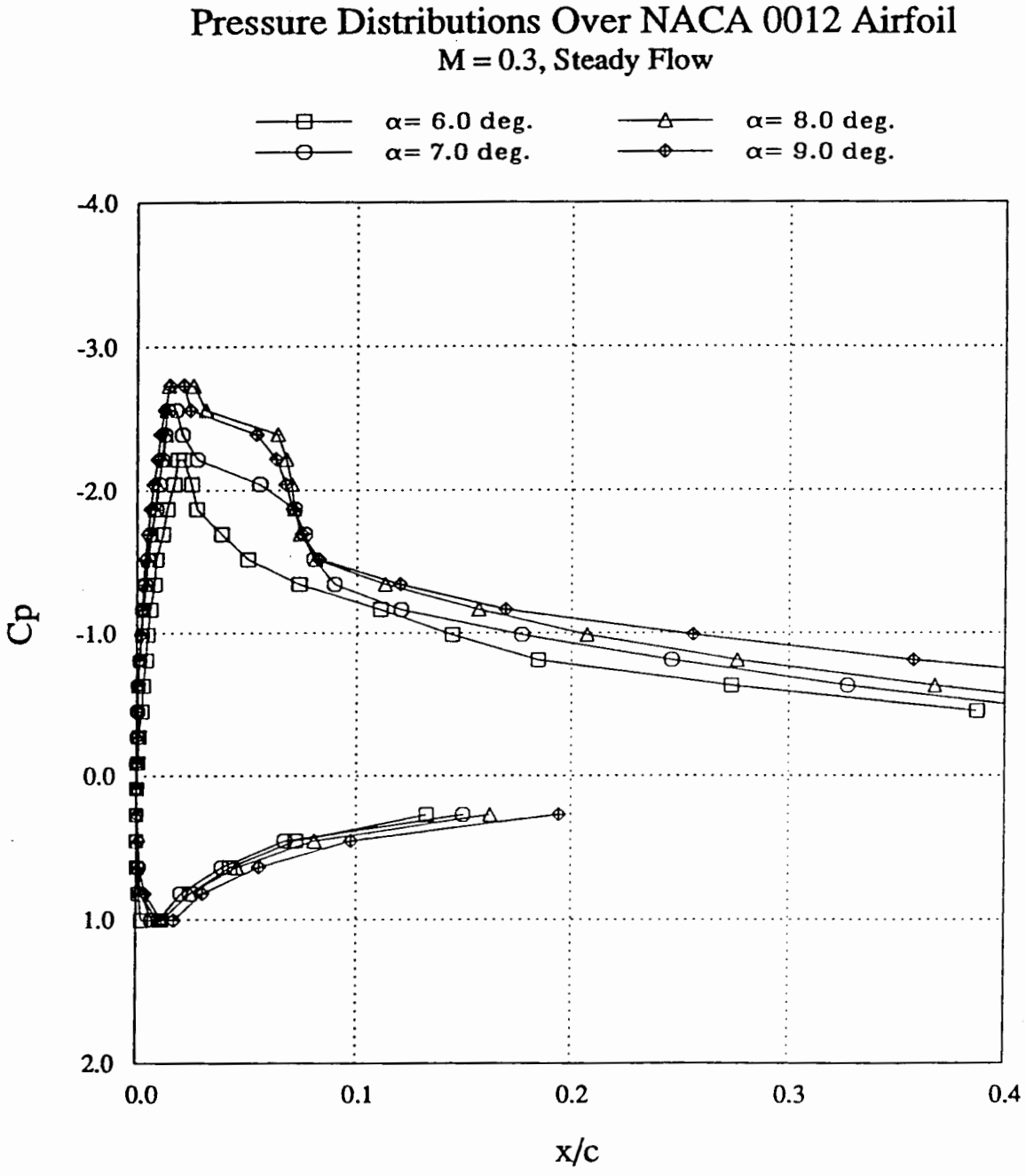
NACA 0012 AIRFOIL

USING

NAVIER–STOKES METHOD


Computed Cf, M = 0.3, Re = 0.54 mil. (Chen-Thyson Transition M
CF
a = 6.0 deg.
a = 7.0 deg.
a = 8.0 deg.
a = 10.0 deg.
Skin Friction, Cf
0.0050
0.0025
0.0000
-0.0025
0.05
0.10
0.15
Chordwise Location, x/c


a=10+2sin(t), a=12 up, Re = .54 mil.
0.00
-0.02
-0.04
0.02
0.04
0.06
0.08
x/c
Cf


Pressure Distributions Over NACA 0012 Airfoil
M = 0.3, Steady Flow
α= 6.0 deg.
α= 7.0 deg.
α= 8.0 deg.
α= 9.0 deg.
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
Cp
0.0
0.1
0.2
0.3
0.4
x/c

SUMMARY

Separation Bubbles on NACA 65-213 and NACA 0012 could be predicted successfully with a modified Chen-Thyson transition model